



## Article Info

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## Augmented Reality Knowledge Vault for Educational Institutions Using the Fisher–Yates Shuffle Algorithm

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This study evaluates the effectiveness of an Augmented Reality (AR) Knowledge Vault enhanced with the integration of Fisher–Yates Shuffle Algorithm for improving learning outcomes among undergraduate students in Educational Institutions. Fifty-five students were purposively selected and randomly assigned to experimental and control groups with 25 students in each group, yielding a final analysed sample of 50 participants. The experimental group used the AR Knowledge Vault with Fisher–Yates Shuffle Algorithm, while the control group relied on a marker-based tools system. Learning performance was assessed across three parameters: engagement, retention and motivation levels. Results showed that students in the AR Knowledge Vault with Fisher–Yates Shuffle Algorithm group achieved remarkably higher engagement and retention level (Mean Value = 74.76 and 71.34) compared to the control group (Mean Value = 59.75 and 58.21 respectively). Motivation level also increased from 6.05 to 7.58 with the AR Knowledge Vault enhanced with Fisher–Yates Shuffle Algorithm. These gains highlight the impact of interactive, varied and algorithmically structured content enabled by the Fisher–Yates Shuffle Algorithm. The system was developed using ASP.NET with C#, Bootstrap, jQuery, and SQL Server. Overall, the findings suggest that AR Knowledge Vault enhanced with algorithmic content variation can meaningfully improve learning experiences and academic outcomes.

**Keywords:** Augmented Reality, Randomisation, Knowledge Vault, Fisher–Yates Shuffle Algorithm and Educational Institutions.

## 1. Introduction

Augmented Reality (AR) is emerging powerful tool that visualisation and interaction, such as science, can transform traditional education into a more mathematics, history and environmental studies [5]. interactive and engaging experience. These They allow learners to visualise abstract concepts, technologies integrate digital information into the actively participate in lessons, and connect classroom physical world, enabling users to interact with virtual theory with real-world applications. Despite this objects within their real-life environment in real time potential, the effective use of AR in education still [1]. Unlike Virtual Reality (VR) [2], which immerses faces several challenges [6].

users in a fully artificial environment, Augmented Reality (AR) enriches the real world by overlaying 3D A major obstacle is the lack of awareness and models, animations, or contextual data onto physical understanding among both educators and students surroundings. This is typically achieved throughout how Augmented Reality (AR) games can devices such as head-mounted displays (HMDs), enhance teaching and learning. In the work of [7], this holographic screens, and handheld devices like gap is further widened by limited technical skills and smartphones and smart glasses [3].

insufficient training for teachers, making classroom integration difficult. High development costs, According to [4], Augmented Reality (AR) offers inadequate infrastructure and unequal access to digital immersive and interactive learning opportunities by devices also limit the widespread adoption of allowing learners to visualise abstract concepts, Augmented Reality (AR), particularly in under-manipulate digital objects, and engage in experiential resourced schools.

learning. This capability makes Augmented Reality Another key issue is the absence of strong curriculum (AR) a powerful pedagogical tool for bridging the gap models and pedagogical frameworks to guide the use between theoretical knowledge and real-world of Augmented Reality (AR) in formal education. application, particularly in subjects requiring Coupled with resistance to technological change from

some educators and administrators, this uncertainty slows down adoption [8]. As a result, a digital divide emerges, preventing many students and schools from benefiting from innovative learning tools that could significantly boost academic performance and skill development [9]. Limited awareness, lack of training, infrastructural barriers, high costs, resistance to change and weak integration strategies remain critical problems. If left unaddressed, these challenges will continue to hold back the transformative potential of Augmented Reality (AR) games in education [10]. To effectively address this problem, an algorithmic-based approach should be integrated into the Augmented Reality (AR) platform. This integration will enhance the reliability and impartiality of the randomisation processes, ensuring more consistent and unbiased outcomes.

One of the most effective algorithms for unbiased randomization is the Fisher-Yates shuffle (also known as the Knuth shuffle). This algorithm provides a simple yet powerful way to rearrange elements in an array or list into a random order without sacrificing performance or fairness [11]. Because of its efficiency and reliability, the Fisher-Yates shuffle has become a preferred tool for developers in diverse domains, including mobile gaming, educational applications and machine learning [12]. This model seeks to combine Augmented Reality (AR) immersive capabilities with intelligent randomisation to create an adaptive learning platform. The game leverages Augmented Reality (AR) technology to overlay quiz-based knowledge vaults, challenges and interactive 3D content within the learner’s physical environment while the Fisher-Yates Shuffle ensures that quiz questions and tasks are randomised to maintain novelty. This approach addresses key limitations of conventional Augmented Reality (AR) educational tools by enhancing interactivity, reducing repetition, and promoting active learning [13].

The Fisher-Yates Shuffle Algorithm works in  $O(n)$  time complexity. According to [14], the assumption is that a given function  $\text{rand}()$  generates a random number in  $O(1)$  time. The idea is to start from the last element and swap it with a randomly selected element from the whole array (including the last). Now consider the array from 0 to  $n-2$  (size reduced by 1) and repeat the process till it hits the first element. Below shows the mathematical representation Fisher-Yates Shuffle Algorithm and its flowchart.

The algorithm below shows a mathematical representation of Fisher-Yates shuffle algorithm in C#

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$$\text{section}\{\text{Mathematical Representation of the Fisher-Yates Shuffle}\}$$

Let the array be

$$A = [a_1, a_2, \dots, a_n]$$

For each iteration

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$$i = n, n-1, \dots, 2,$$

choose

$$j \sim \text{Uniform}\{1, \dots, i\},$$

and swap

$$(A[j], A[i]) \leftarrow (A[i], A[j]).$$

The final array is a uniform random permutation

$$\pi(A) = \left( \prod_{i=n}^2 S(i, j_i) \right) A,$$

where  $(S(i, j))$  is the swap operation exchanging entries  $i$  and  $j$ .

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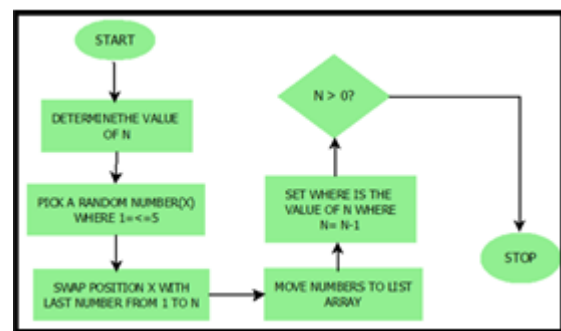


Figure 1: Flowchart representation of Fisher-Yates shuffle algorithm [14]

## 2. Review of Related Literature

Augmented Reality (AR) enriches the physical world by overlaying digital content onto real environments, allowing learners to interact with virtual objects in meaningful, hands-on ways. Research has consistently shown that Augmented Reality (AR) can boost learner motivation, attention and understanding mostly in STEM and other visually intensive subjects [15]. According to [16], meta-analyses and systematic reviews highlight that Augmented Reality (AR) works best when it is integrated into lessons with clear educational goals, rather than being used as a novelty.

In the work of [17], it was stated that elements such as points, badges, countdown timers and instant feedback help maintain student interest and encourage repeated practice. In quiz-based learning, the unpredictability of randomised questions prevents rote memorisation and promotes deeper thinking and knowledge transfer. When combined with adaptive difficulty and real-time feedback, these features guide learners toward mastery while keeping them in a productive state of challenge and engagement [18]. Augmented Reality (AR) increases these mechanics by situating tasks and questions within immersive, context-rich environments, making learning not only more engaging but also more relevant to real-world experiences.

Practical applications already demonstrate this potential. Several Augmented Reality (AR) -based educational apps, for example, allow students to explore 3D models of medical devices, cultural artefacts, or biological structures while engaging in randomised quizzes powered by the Fisher-Yates shuffle algorithm. This ensures that questions appear in varied orders, minimizing repetition and sustaining curiosity [19]. User studies of these systems often report high satisfaction, increased enthusiasm and short-term gains in knowledge recall. However, most existing projects remain small in scale, focusing primarily on usability and technical feasibility rather than conducting rigorous, long-term evaluations of learning outcomes [20].

Augmented Reality (AR) technology complements the Fisher-Yates Shuffle by creating interactive, immersive environments that enrich the visual and experiential aspects of learning. Through Augmented Reality (AR) interfaces, learners can explore 3D representations of historical sites, cultural artifacts, or environmental phenomena, gaining a deeper understanding through experiential engagement [21]. When combined with randomization, Augmented Reality (AR) offers the potential to deliver highly engaging and contextually relevant educational experiences particularly in subjects like history and environmental science, where visual context enhances comprehension.

Quiz-Based Knowledge Vault Games that was proposed by [22], were designed to test and reinforce players' knowledge across different subjects. These games typically present randomised questions in formats such as multiple-choice, fill-in-the-blank and true-or-false, often within time limits to maintain excitement and challenge [23]. By using randomisation, no two sessions are exactly alike, keeping learners engaged while reinforcing knowledge through repetition. Many of these games also provide instant feedback, allowing players to identify their strengths and weaknesses, improve their cognitive skills, and retain information more effectively. Beyond entertainment, such quiz-based games are now widely used in education to make learning both interactive and enjoyable [24].

In the work of [25], they developed an android-based learning app that combined Augmented Reality (AR) with the Fisher-Yates Shuffle to randomise quiz questions on medical equipment however it could not provide a reliable and impartial randomization process, which limited its ability to produce consistent and unbiased outcomes. Using marker-based Augmented Reality (AR) tracking, they visualised 3D models of medical tools, creating an engaging and interactive learning experience. The randomisation element prevented quizzes from becoming repetitive, which improved user engagement and knowledge retention [26]. Also in the work of [27], they created an Android culture education game aimed at teaching

Indonesian culture to children. By applying the Fisher-Yates Shuffle, quiz questions were randomized to keep learning dynamic and prevent rote memorisation. According to [28], many developers faced technical hurdles in optimising the algorithm for various screen sizes and device performance levels.

As opined by [29], an android game to promote knowledge of Javanese Batik culture was designed that gave a low result using Fisher-Yates Shuffle algorithm however performance optimization posed challenges, particularly in rendering the intricate details of Batik designs across devices with varying processing power. In the work of [30], they presented a model by integrating Fisher-Yates Shuffle in an Educational Quiz Game for Enhanced Learning Engagement. By using the Fisher-Yates Shuffle to prevent answer memorisation, the game-maintained novelty and encouraged deeper learning. Employing a mixed-methods approach, the researchers gathered both qualitative feedback and quantitative performance data. Results showed measurable improvements in engagement and academic outcomes [31]. A key difficulty was striking the right balance between educational rigour and enjoyable gameplay to keep students motivated without overwhelming them [32]. Findings showed that students who used the tool demonstrated stronger comprehension and improved performance in biology assessments. The main challenge lay in accurately representing complex biological concepts while keeping the models intuitive and interactive [33]. In the research carried out by [34], the results indicated that students became more engaged and demonstrated stronger learning outcomes. However, technical challenges arose in rendering AR content consistently across devices, mirroring difficulties noted in other studies. It was opined by [35] that the game significantly boosted historical knowledge and engagement, with users responding positively to the intuitive design. However, the challenge lay in ensuring that randomisation supported rather than disrupted the educational flow of the game [36].

According to [37], many AR-based learning platforms such as marker-based visualisation tools prioritize visual immersion to enhance learner engagement and conceptual understanding. Despite these benefits, such systems often lack robust algorithmic structures for organising and randomising learning objects or activities, leading to repetitive item sequences that undermine adaptability and instructional fairness. Integrating the Fisher–Yates Shuffle Algorithm offers a practical solution by introducing a reliable and unbiased randomisation mechanism. When embedded within an AR educational environment, the algorithm enhances fairness, reduces predictability and supports improved retention and personalised learning outcomes [38].

### 3. Methodology

#### 3.1 Research Design

A quasi-experimental pretest–posttest design was used to compare the effectiveness of the AR Knowledge Vault with Fisher–Yates Shuffle Algorithm over the use of a marker-based visualisation tools. Two groups were created; an experimental group using the AR Knowledge Vault with Fisher–Yates Shuffle Algorithm and a control group using marker-based visualisation tools. The AR platform incorporated the Fisher–Yates Shuffle Algorithm to randomise learning modules and maintain engagement.

#### 3.2 Participants

Fifty-five undergraduate students from the Department of Information Systems and Technology, Southern Delta University, Ozoro were selected through purposive sampling. After random assignment, they were divided into two groups of experimental and controlled groups with 25 students in each group while the final analyzed sample comprised 50 students with comparable characteristics.

#### 3.3 Data Collection Instruments

Three validated instruments with reliability above 0.80 were used:

- i. **Engagement Scale:** A structured questionnaire measuring students' attention, participation, and overall interaction during learning activities.
- ii. **Retention Test:** A post-intervention knowledge assessment designed to evaluate recall and understanding of key concepts.
- iii. **Motivation Survey:** A Likert-scale instrument assessing students' level of interest, enthusiasm, and willingness to engage with the learning content.

#### 3.4 Procedure

The experimental group used the AR Knowledge Vault with Fisher–Yates Shuffle Algorithm for four weeks, while the control group received the same content through marker-based tools within same period. Post-intervention assessments for engagement, retention and motivation were administered simultaneously across both groups.

#### 3.5 Data Analysis

Descriptive statistics and independent-samples t-tests were used to compare groups, with Cohen's *d* reported for effect sizes. Significance was set at  $p < .05$ . Ethical protocols were followed, including informed consent, confidentiality and voluntary participation.

Table 1: Sample Table

Group	Description	Sample Size (n)	Treatment Condition
Experimental Group	Students assigned to the AR system with Fisher–Yates Shuffle Algorithm.	n = 25	Enhanced AR with randomization
Control Group	Students assigned to use the marker-based tools without randomization	n = 25	Conventional AR learning
Total	Combined participants across both groups.	N = 50	—

Table 2: Variables Table

Variable Type	Variable Name	Description / Measurement	Scale of Measurement
Independent Variable	AR Instructional Condition	Whether the student used AR with Fisher–Yates randomization or standard AR.	Nominal
Dependent Variable 1	Engagement Score	Students' cognitive, behavioural, and affective engagement scores from questionnaire. Multiple-choice test measuring	Interval
Dependent Variable 2	Achievement Score	conceptual understanding (pretest/posttest). Delayed test measuring	Interval
Dependent Variable 3	Retention Score	long-term retention.	Interval
Control Variables	Age, prior AR experience, course background	Used to ensure that differences are not due to demographic or academic factors.	Nominal/Interval

#### 3.6 Key Features of the Proposed System

- i. **Dynamic AR Interface:** The system is capable of scanning real-world surfaces and overlaying questions and objects in 3D space, creating an interactive and realistic game environment.

- ii. **Intelligent Randomisation:** Each gameplay session presents randomised questions and answers, reducing repetition and fostering critical thinking skills.
- iii. **Real-Time Feedback:** Users receive instant evaluation of their responses, enabling adaptive learning and continuous improvement.
- iv. **User Profile and Performance Tracking:** The system monitors user progress, game scores, and knowledge retention levels over time, dynamically adjusting the difficulty level to suit individual learners.
- v. **Lag-Free Visual Rendering:** By applying optimised Augmented Reality (AR) rendering techniques and lightweight assets, the system ensures smooth and responsive interactions, even on standard mobile devices.
- vi. **Gamified Learning Experience:** Learners are motivated through the awarding of points, badges, and unlockable content, sustaining interest and engagement throughout their academic journey.
- vii. **Scalable and Educationally Robust Design:** Built on the Object-Oriented Methodology (OOM) and enhanced with AR integration, the system provides a highly engaging and scalable learning platform tailored to the needs of students in a tertiary institution.

- randomisation, scoring mechanisms, and difficulty adjustments. It ensures that the experience remains balanced, adaptive, and engaging.
- iii. **AR Rendering Engine:** Handles real-time visualisation by merging virtual elements with the physical environment. It manages object placement, animations, and rendering optimisations to maintain smooth performance and prevent lag.
- iv. **Data Management Module:** Oversees storage and retrieval of critical information such as user profiles, question banks, performance logs, and game statistics. It supports persistent data storage to track learner progress across multiple sessions.
- v. **Feedback and Adaptation Module:** Analyses user interactions to provide immediate feedback and adjust the difficulty level or question type dynamically. This adaptive learning capability helps sustain engagement while enhancing knowledge retention.

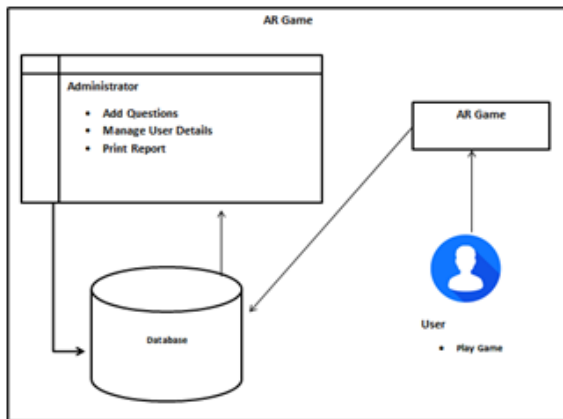


Figure 2: Architecture of the system

### 3.7 Components of the System

The Augmented Reality (AR) Knowledge Vault Game features an architectural design that highlights the system’s core components, their interactions, and the overall workflow. This architecture serves as a blueprint for guiding system development, ensuring that all functional requirements are addressed cohesively and efficiently. The primary modules include:

- i. **User Interface Module:** Manages all user interactions. Using Augmented Reality (AR) - enabled mobile devices, it captures real-world environment data, overlays educational content in 3D, and records user inputs such as quiz responses and navigation commands.
- ii. **Game Logic Module:** Houses the core algorithms that drive gameplay, including question

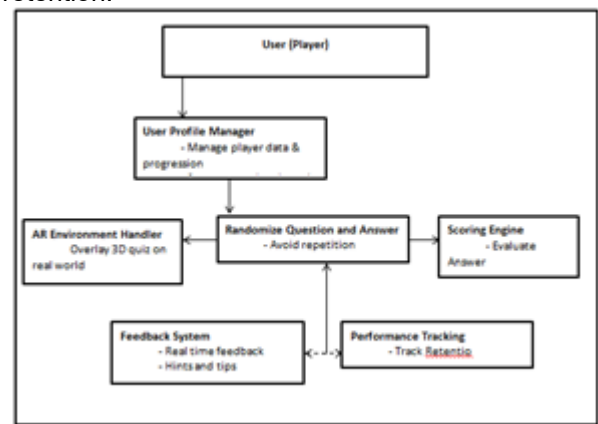


Figure 3: High-level model of the System

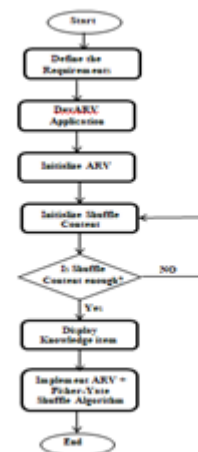


Figure 4: Flowchart of the System

### 3.8 System Design

The system architecture is divided into three major layers:

- i. **Presentation Layer:** This layer is responsible for user interaction. It includes the graphical user interface and the Augmented Reality (AR) interface, allowing

users to visualise game content overlaid in the real-world environment. Unity3D and Augmented Reality (AR) SDKs (like Vuforia or ARCore) will be used for rendering and real-time object tracking.

- ii. **Business Logic Layer:** This encapsulates all game rules, algorithms and interaction flows. It governs how the game operates such as question sequencing, adaptive difficulty and score evaluation ensuring consistency and fairness in gameplay.

**Data Layer:** This layer handles the storage and retrieval of data. It interacts with local or cloud-based databases to manage user data, question banks, historical scores and progress tracking.



**Figure 5:** Hierarchy chart for the overall system

### 3.9 Software and Hardware Specification

This section outlines the essential software tools and hardware components utilised in the development, deployment and testing of the Knowledge Vault Augmented Reality (AR) Game system. The platform was built using the ASP.NET framework for responsive application development, with C# serving as the primary programming language. For data management, SQL Server was employed as the backend database solution, ensuring efficient storage, retrieval and security of user and gameplay data. The minimum hardware setup ensures smooth development, testing and user experience.

**Processor:** Intel Core i5 or higher for handling development tools and local server operations efficiently with a minimum of 8GB, 100GB free disk space for storing project files, databases, logs and backups, 15-inch HD or higher for better design visibility and a stable internet connection for remote repository access and cloud deployment if needed.

### 3.10 UI/UX Implementation

The UI/UX design of the Knowledge Vault Augmented Reality (AR) Game system was developed with a strong focus on seamless navigation, responsiveness and interactivity factors that are critical for sustaining user engagement and motivation in educational environments. The goal was to create an intuitive, visually appealing and immersive interface that enriches the learning experience through simplicity, consistency and modern design patterns.

To achieve this, HTML5 and CSS3 were used for structuring and styling the application's pages, while Bootstrap 4.5 ensured cross-device responsiveness. Leveraging Bootstrap's grid system and component library enabled the quick implementation of standardised elements such as buttons, modals, alerts and card layouts. These components were further customised to align with the application in the tertiary institution's platform.

For interactivity, JavaScript and jQuery were employed to provide real-time responses to user actions without requiring full-page reloads. This allowed the integration of animations, transitions and dynamic content updates, which are particularly vital in an Augmented Reality (AR)-based learning environment. jQuery further simplified DOM manipulation and AJAX operations, enabling asynchronous communication with the backend to fetch and display quiz questions, scores and progress data seamlessly. Additionally, AR.js and A-Frame libraries were considered for integrating augmented reality features, ensuring learners can interact with 3D educational objects and scenes directly from their browser without additional plugins. These tools were embedded into the frontend via WebGL for rendering real-time 3D content.

### 3.11 Database Implementation

The database for the Knowledge Vault Augmented Reality (AR) Game system was implemented using Microsoft SQL Server, selected for its scalability, performance and seamless integration with ASP.NET. The database serves as the backbone of the application, managing critical data such as user profiles, game questions, scores, AR content and learning progress.

A relational database model was adopted to ensure data integrity and structured access. Tables were normalized up to the third normal form (3NF) to minimize redundancy and maintain consistency. Key entities include Users, Questions, Scores, GameSessions and Achievements, which are interconnected through primary and foreign keys, forming a robust entity-relationship (E-R) model. To improve efficiency, stored procedures were employed for repetitive operations such as inserting users, updating scores, and retrieving random questions. Indexing on key columns (e.g., UserID and SessionID) further optimised query performance, especially during real-time gameplay. Data security was enforced using SQL Server's role-based authentication, parameterised queries to prevent SQL injection, and routine backups for durability and disaster recovery. Integration with the ASP.NET application was achieved through Entity Framework, enabling object-relational mapping (ORM) for seamless CRUD operations and reduced boilerplate code. This efficient and secure design supports the system's dynamic and interactive features, ensuring real-time data access, user

tracking, and adaptive learning capabilities essential for gamification in education.

## 4. Results and Discussion

### 4.1 Results

The table below shows the impact of the Augmented Reality (AR) Knowledge Vault with the Fisher–Yates Shuffle Algorithm considering student’s engagement, retention and motivation against the existing system the marker-based tools without randomization.

**Table 3:** Outcomes and Results

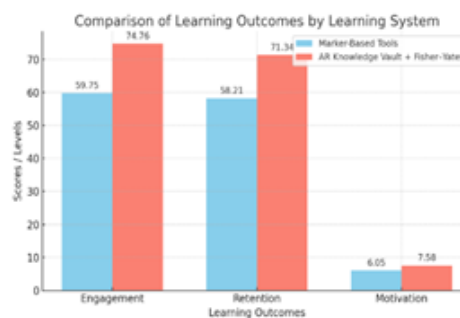
Metric	Existing Mean	AR Vault Mean	t-value	p-value	Cohen’s d	Effect Size Interpretation
Engagement	59.75	74.76	8.612	<.001	1.722	Very Large Effect
Retention	58.21	71.34	6.288	<.001	1.258	Large Effect
Motivation	6.05	7.58	6.625	<.001	1.325	Large Effect

- i. **Engagement** scores were significantly higher for students using the Augmented Reality (AR) Knowledge Vault with the Fisher–Yates Shuffle Algorithm, with a mean of 74.76 compared to 59.75 under the marker-based tools system.
- ii. **Retention** also improved notably in the Augmented Reality (AR) Knowledge Vault with the Fisher–Yates Shuffle Algorithm group achieving a mean score of 71.34 versus 58.21 for the existing system of the marker-based tools system.
- iii. **Motivation** increased from a mean of 6.05 in the group of the marker-based tools system to 7.58 in the Augmented Reality (AR) Knowledge Vault with the Fisher–Yates Shuffle Algorithm group.

### 4.2 Discussion

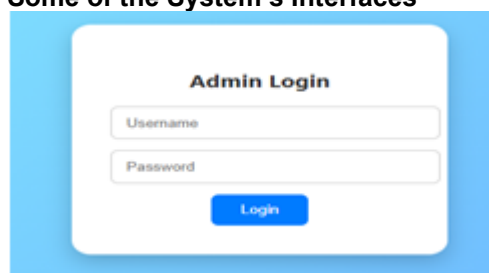
The results show that the Augmented Reality (AR) Knowledge Vault with the Fisher–Yates Shuffle Algorithm significantly enhances students’ learning experiences. Higher engagement levels can be linked to the system’s dynamic and interactive content, supported by the Fisher–Yates Shuffle Algorithm, which minimizes repetition and maintains attention. The improved retention scores indicate that the Augmented Reality (AR) Knowledge Vault with the Fisher–Yates Shuffle Algorithm environment supports stronger memory formation by combining visual, auditory and hands-on interaction which is key elements of effective multimedia learning. Similarly, the boost in motivation suggests that students found the

Augmented Reality (AR) Knowledge Vault with the Fisher–Yates Shuffle Algorithm activities more appealing and rewarding. The novelty, interactivity and subtle gamification likely increased their interest and sustained participation. Overall, the findings demonstrate that integrating AR with algorithmic content variation such as the Fisher–Yates Shuffle Algorithm offers substantial advantages over traditional methods, making it a promising tool for enriching modern teaching and learning practices.

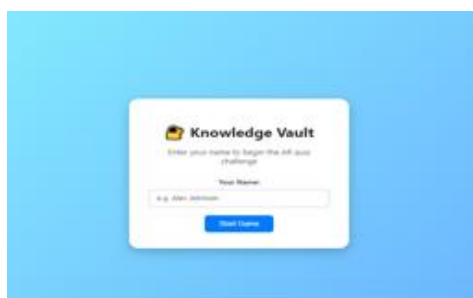


**Figure 6:** Bar chart showing the comparison between AR with Fisher-Yates and Marker- Based tools

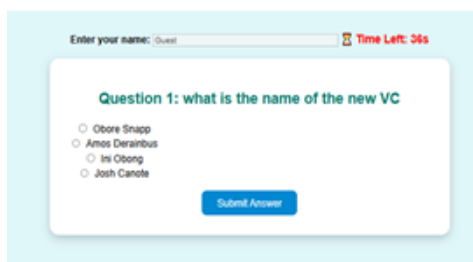
### Some of the System’s Interfaces



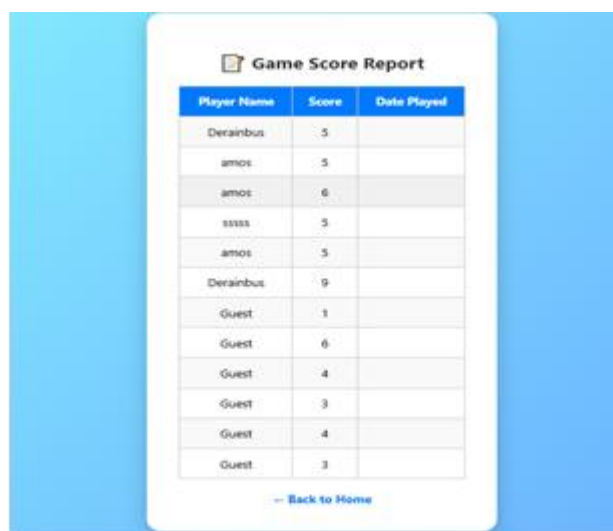
**Figure 7:** The Admin login interface



**Figure 8:** The home page



**Figure 9:** The game page



Player Name	Score	Date Played
Derainbus	5	
amos	5	
amos	6	
sssss	5	
amos	5	
Derainbus	9	
Guest	3	
Guest	6	
Guest	4	
Guest	3	
Guest	4	
Guest	3	

Figure 10: The game report page

## 5. Summary and Conclusion

This study investigated the effectiveness of the Augmented Reality (AR) Knowledge Vault with the Fisher–Yates Shuffle Algorithm among undergraduate students in the Department of Information Systems and Technology at Southern Delta University, Ozoro. Fifty-five students were purposively selected and randomly assigned to experimental and control groups, resulting in a final analyzed sample of 50 participants with comparable characteristics. The experimental group used the AR Knowledge Vault Knowledge Vault Fisher–Yates Shuffle Algorithm, while the control group relied on marker-based tools system. The findings revealed substantial learning gains associated with the AR-enhanced system with the integration of the Fisher–Yates Shuffle Algorithm considering three major parameters; engagement, retention and motivation levels. Engagement levels were significantly higher for the AR Knowledge Vault Fisher–Yates Shuffle Algorithm group ( $M = 74.76$ ) compared to the marker-based group ( $M = 59.75$ ). Retention followed a similar trend, with the AR Fisher–Yates Shuffle Algorithm group scoring a mean of 71.34 versus 58.21 in the control group. Motivation also increased meaningfully, rising from 6.05 under the traditional system to 7.58 with the AR Knowledge Vault Fisher–Yates Shuffle Algorithm. These improvements point to the effectiveness of interactive, varied and algorithmically structured content made possible through the Fisher–Yates Shuffle Algorithm. Overall, the integrated results suggest that the AR Knowledge Vault Fisher–Yates Shuffle Algorithm offers a compelling pedagogical advantage over marker-based tools system. Its rich multimedia environment reduced content repetition and subtle gamification fostered higher engagement, deeper information processing and stronger intrinsic motivation. Consequently, this study supports the

argument that Augmented Reality usually when enhanced with algorithmic content variation such as Fisher–Yates Shuffle Algorithm can play a transformative role in modern instructional practice by enhancing students' learning experiences and improving key academic outcomes.

## Conflict of Interest

The authors declare no conflict of interest.

## References

- Karakus, M., Ersozlu, A., and Clark, A. C. (2019). Augmented Reality Research in Education: A Bibliometric Study. *Eurasia Journal of Mathematics, Science and Technology Education*, 15(10), em1755. <https://doi.org/10.29333/ejmste/103904>
- Lai, K.-W. K., and Chen, H.-J. H. (2023). A Comparative Study on the Effects of a VRand PC Visual Novel Game on Vocabulary Learning. *Comput. Assist. Lang. Learn.* 36 (3), 312–345. doi:10.1080/09588221.2021.1928226
- Korosidou, E. (2024). The Effects of Augmented Reality on Very Young Learners' Motivation and Learning of the Alphabet and Vocabulary. *Digital 4* (1), 195–214. doi:10.3390/digital4010010
- Huang, C. Y., Wang, H. Y., Yang, C. L., and Shiau, S. J. (2020). A Derivation of Factors Influencing the Diffusion and Adoption of an Open Source Learning Platform. *Sustainability*, 12(18), 7532. <https://doi.org/10.3390/su12187532>
- Scherer, R., Siddiq, F., and Tondeur, J. (2019). The Technology Acceptance Model (TAM): A Meta-Analytic Structural Equation Modeling Approach to Explaining Teachers' Adoption of Digital Technology in Education. *Computers & Education*, 128, 13-35. <https://doi.org/10.1016/j.compedu.2018.09.009>
- Al-Ansi, A., Jaboob, M., Garad, A., and Al-Ansi, A. (2023). Analyzing Augmented Reality (AR) and Virtual Reality (VR) Recent Development in Education. *Soc. Sci. Humanit. Open* 8, 100532. doi:10.1016/j.ssaho.2023.100532
- Hung, H., and Yeh, H. (2023). Augmented-Reality-Enhanced Game-Based Learning in Flipped English Classrooms: Effects on Students' Creative Thinking and Vocabulary Acquisition. *J. Comput. Assisted Learn.* 39 (6), 1786–1800. doi:10.1111/jcal.12839
- Kiryakova, G., Angelova, N., and Yordanova, L. (2018). The Potential of Augmented Reality to Transform Education into Smart

- Education. *TEM Journal*, 7(3), 556-565. <https://doi.org/10.33578/pjr.v3i4.7433>
9. Kim, S. J., Jeong, Y., Park, S., Ryu, K., and Oh, G. (2018). A Survey of Drone Use for Entertainment and AVR (Augmented and Virtual Reality). In *Augmented Reality and Virtual Reality* (pp. 339-352). Springer. [https://doi.org/10.1007/978-3-319-64027-3\\_23](https://doi.org/10.1007/978-3-319-64027-3_23)
10. Anderson, J. P., Clarke, T. S., and Martinez, L. A. (2021). Engagement Strategies for Mobile AR Learning in Higher Education. *International Journal of Mobile and Blended Learning*, 13(2), 45–62.
11. Chang, Y. S., Hu, K. J., Chiang, C. W., and Lugmayr, A. (2020). Applying Mobile Augmented Reality (AR) to Teach Interior Design Students in Layout Plans: Evaluation of Learning Effectiveness Based on the ARCS Model of Learning Motivation Theory. *Sensors*, 20(1), 105. <https://doi.org/10.3390/s20010105>
12. Lubis, F., Utama, A., and Wibowo, P. (2022). Shuffled-Question AR Quiz for Indonesian Cultural Heritage Learning. *ICT in Education Journal*, 11(3), 140–156.
13. Bursali, H., and Yilmaz, R. M. (2019). Effect of Augmented Reality Applications on Secondary School Students' Reading Comprehension and Learning Permanency. *Computers in Human Behavior*, 95, 126-135. <https://doi.org/10.1016/j.chb.2019.01.035>
14. Seefried, S., Müller, F., and Schmitt, T. (2024). Learning Foreign Language Vocabulary Through Task-Based Virtual Reality Environments. *J. Educ. Comput. Res.* 61 (3), 567–589. doi:10.1177/07356331231234567
15. Rohmah, W. A., Asriyanik, A. and Apriyandari, W. (2020). Implementation of the Algorithm Fisher Yates Shuffle on Game Quiz Environment, *J. Informatics Telecommun. Eng.*, vol. 4, no. 1, pp. 161–172, doi: 10.31289/jite.v4i1.3863.
16. Lee, J., Kim, J., and Choi, J. Y. (2019). The Adoption of Virtual Reality Devices: The Technology Acceptance Model Integrating Enjoyment, Social Interaction, and Strength of the Social Ties. *Telematics and Informatics*, 39, 37-48. <https://doi.org/10.1016/j.tele.2018.12.006>
17. Anazia E. K, Ojei, E. and Okpor, M.D. A (2024). Fuzzy Logic-Based Automobile Fault Detection System Using Mamdani Algorithm *International Journal of Scientific Research and Management (IJSRM)*,
- ||Volume||12||Issue||03||Pages||1081-1093||2024||  
Website: <https://ijsrm.net> ISSN (e): 2321-3418 DOI: 10.18535/ijsrm/v12i03.ec06. (ONLINE) INDIA
18. Ojugo, A. A. Odiakaose, C. C. Emord, F. U. Ejeh, P. O. Adigwe, W. Anazia, K.W, and Nwozor, B. (2023). Forging a Learner-Centric Blended-Learning Framework Via an Adaptive Content-Based Architecture
19. Anazia, E. K. Eti, E. F. Ovili, P. H. and Ogbimi, O. F. (2024). Speech-To-Text: A Secured Real-Time Language Translation Platform for Students, *FUDMA Journal of Sciences (FJS)* Vol. 8 No. 6, December, 2024, DOI: <https://doi.org/10.33003/fjs-2024-0806-2890>.
20. Arnold, A. O. Christopher, Chukwufunaya, O. Emordi, F. Ako, R. E. Adigwe, W. Anazia, E. K. and Geteloma, V. (2023). Evidence of Students' Academic Performance at the Federal College of Education Asaba Nigeria: Mining Education Data, Knowledge Engineering and Data Science (KEDS) pISSN 2597-4602, Vol 6, No 2, pp. 145–156.
21. Schorr, I., Plecher, D. A., Eichhorn, C., and Klinker, G. (2024). Foreign Language Learning Using Augmented Reality Environments: A Systematic Review. *Front. Virtual Real.* doi:10.3389/frvir.2024.1288824
22. Li, J., and Cesar, P. (2023). Social Virtual Reality (VR) Applications and User Experiences, In *Immersive Video technologies*. Amsterdam, Netherlands: Elsevier, 609–648. doi:10.1016/B978-0-32-391755-1.00028-6
23. Kurniawan, I., and Sauda, S. (2021). Implementasi Algoritma Fisher Yates Shuffle Pada Aplikasi Belajar Huruf Hijaiyah. *Journal of Information Technology Ampera*, 2(3), 139–149. <https://doi.org/10.51519/journalita.volume2.issue3.year2021.page139-149>
24. Song, C., Shin, S.-Y., and Shin, K.-S. (2023). Optimizing Foreign Language Learning in Virtual Reality: a Comprehensive Theoretical Framework Based on Constructivism and Cognitive load theory (VR-CCL). *Appl. Sci.* 13 (23), 12557. doi:10.3390/app132312557
25. Airmawani, H., Usman, U., and Sarudin, S. (2020). Implementation of the Fisher Yates Shuffle Algorithm in Medical Equipment Learning Applications with Augmented Reality Technology. *International Journal of Education and Development Using Information and Communication Technology*, 16(2), 45–56.
26. Nurfitri, K., Abdurrozzaq, I., and Karaman, J. (2023). Penerapan Algoritma Fisher Yates

- Shuffle Pada Game Edukasi, English for Children, di LKP Elite English School Ponorogo. *Digital Transformation Technology*, 3(2), 438–449. <https://doi.org/10.47709/digitech.v3i2.2885>
27. Aditiya, D., Juliasari, M., and Ariyani, R. (2022). Application of the Fisher Yates Shuffle Algorithm Method in Android-based Culture Education Games. *JOURNAL of Educational Technology and Media*, 13(4), 100–115.
28. Khodabandeh, F., and Mombini, A. (2024). Exploring the Effect of Augmented Reality Technology on High School Students' Vocabulary Learning, Personality Traits, and Selfefficacy in Flipped and Blended Classes. *Educ. Inf. Technol.* 29 (12), 16027–16050. doi:10.1007/s10639-024-12486-5
29. Rahman, H., Shofy, T., and Andryana, R. (2021). Implementation of Fisher-Yates Shuffle Algorithm in Android-Based Javanese Batik Culture Education Game. *International Journal of Educational Technology*, 14(1), 23–37
30. Wang, X., and Chen, Y. (2023). Integrating Fisher-Yates shuffle in an Educational Quiz Game for Enhanced Learning Engagement. *Journal of Educational Technology and Systems*, 24(3), 150–165.
31. Li, Y., Ying, S., Chen, Q., and Guan, J. (2022). An Experiential Learning-Based Virtual Reality Approach to Foster Students' Vocabulary Acquisition and Learning Engagement in English for Geography. *Sustainability* 14 (22), 15359. doi:10.3390/su142215359
32. Khan, R.M. I., Ali, A., Kumar, T., and Venugopal, A. (2023). Assessing the Efficacy of Augmented Reality in Enhancing EFL Vocabulary. *Cogent Arts Humanit.* 10 (1), 2223010. doi:10.1080/23311983.2023.2223010
33. Kim, S., Lee, J., Choi, Y., and Lim, H. (2022). Gamified Learning in Biology Using Augmented Reality and Fisher-Yates Shuffle. *Educational Technology & Society*, 25(1), 24–38.
34. Saha, A., and Banerjee, S. (2021). Augmented Reality–Based Learning Game for Mathematics Education With Fisher-Yates Shuffle. *Journal of Educational Technology Development and Exchange*, 14(2), 45–62.
35. Zailuddin, D., Bastian, A., Yuliani, M. S. S., Firmansyah, E., Sarmidi, and Sumaryana, Y. (2024). Engaging Teens in History Through a Mobile Game Utilizing the Fisher-Yates Shuffle Algorithm and Honeycomb UX Design. *International Journal of Interactive Mobile Technologies*, 18(22), 35–49. <https://doi.org/10.3991/ijim.v18i22.50705>
36. Kurniawan, I., and Sauda, S. (2021). Implementasi algoritma Fisher Yates Shuffle Pada aplikasi belajar huruf hijaiyah. *Journal of Information Technology Ampera*, 2(3), 139–149. <https://doi.org/10.51519/journalita.volume2.issue3.year2021.page139-149>,
37. Ibáñez, M. B., and Delgado-Kloos, C. (2018). Augmented Reality for Stem Learning: A Systematic Review. *Computers & Education*, 123, 109–123, DOI:10.1016/j.compedu.2018.05.002
38. Bower, M., DeWitt, D., and Lai, J. W. M. (2020). Reasons Associated with Preservice Teachers' Intention to Use Immersive VR. *British Journal of Educational Technology*, 51(6), 2214–2232, DOI:10.1111/bjet.13009